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Self-related neural response to tailored smoking-cessation messages predicts quitting

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Abstract

Although tailored health interventions can be more effective in eliciting positive behavior change then generic interventions, the underlying neural mechanisms are not yet understood. Ninety-one smokers participated in a functional magnetic resonance imaging (fMRI) session and a tailored smoking-cessation program. We found that increases in activations in self-related processing regions, particularly dorsomedial prefrontal cortex, to tailored messages predicted quitting during a 4-month follow-up.

Over the past decade, a powerful convergence of health communication techniques and information technology has fueled the rapid development of tailored health intervention programs, including web-based programs. Such widely available and affordable health intervention programs can help reduce the staggering health and societal costs of preventable illnesses. Emerging evidence suggests that tailored interventions can be more effective than one-size-fits-all interventions in eliciting positive health-behavior changes, including smoking cessation and weight management[1-2]. Thus, understanding the underlying mechanisms is an important next step.

We hypothesized that self-related processing is a central psychological mechanism underlying the enhanced efficacy of tailored message interventions. Tailored messages typically make references to an individual's life, needs, and interests, as well as to specific obstacles to achieving a desired change. Tailoring itself involves increasing the proportion of recognizable features of the individual in the message, and providing feedback about the

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individual[3]. Thus, an individual receiving tailored messages is expected to engage in self-referential processing and to perceive the messages as self-relevant[4]. In turn, heightened perception of self-relevance could enhance learning and memory, plausibly by greater elaboration during encoding and by fostering a more systematic organization in storage[5]. Thus, self-relevant messages should be more persuasive and effective in producing desired behavioral changes.

If the enhanced efficacy of tailored messages involves self-related processing, then it should also engage brain regions involved in self-related processing. Meta-analyses of functional neuroimaging studies suggest that self-related processing is mediated by a cortical network, including medial prefrontal cortex [mPFC] and precuneus/posterior cingulate regions[6,7]. Although we previously demonstrated that highly tailored smoking-cessation messages indeed activate mPFC and precuneus/posterior cingulate regions[8], it was unclear whether these activations were associated with self-related processing. In the present study, we examined whether the neural response to tailored smoking-cessation messages overlaps with self-related processing regions, determined via an independent Self task and, more critically, whether the activation in these regions predicts subsequent real-life quitting.

We recruited ninety-one smokers interested in quitting (44 females and 47 males; mean age 37.5 years; mean number of cigarettes per day 16.7) for the study, which included 3 sessions and a follow-up phone interview (Supplementary Methods). In Session 1, participants gave written informed consent, and completed a standard assessment about their health, demographic, and psychosocial characteristics relevant to smoking cessation. We used the responses to create tailored smoking-cessation messages for a subsequent intervention. In Session 2, participants completed two fMRI tasks: a Messages Task, to examine brain regions associated with processing of smoking-cessation messages, and a Self-Appraisal Task, to identify brain regions involved in self-related processing. In Session 3, participants completed a web-based tailored smoking-cessation program[9] and were instructed to quit smoking. Four months after the intervention, we interviewed the participants over the phone to determine their smoking cessation status using the standard 7-day point prevalence abstinence (cigarette free for the past 7 days)[10].

During the Messages Task, participants passively received audio-visual blocks of three types of messages: Tailored smoking-cessation messages, Untailored smoking-cessation messages, and Neutral messages (Supplementary Table 1 for examples). Neutral messages were not related to smoking cessation. Untailored messages were smoking-cessation statements applicable to smokers in general, whereas Tailored messages were generated based on the individual's information and thus varied across participants. Untailored and Neutral messages were identical for all participants. In the Self-Appraisal Task[11], participants had to decide using key press whether an adjective presented described them or not (self-referential evaluation condition, "*Self*") or whether the adjective was of positive valence (valence judgment condition, "*Valence*").

The smoking-cessation outcome was available from 87 out of the 91 participants. We categorized participants who remained abstinent during the 4-month follow-up as "Quitters" (n = 45) and the participants who did not succeed in quitting as "Non-Quitters" (n = 42).

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Performance on a surprise memory test demonstrated overall better memory for Tailored than Untailored or Neutral messages, but the memory performance was not associated with quitting (Supplementary Results). We examined brain activation regions associated with self-related processing, tailored message processing, and untailored message processing (Supplementary Figs. 1-2 and Tables 2-4). To identify overlapping brain foci between regions preferentially engaged by tailored message processing (Supplementary Fig. 3 and Table 5) and self-related processing, we used a conjunctive mask of *Tailored* > *Untailored* and Self-Appraisal (*Self* > *Valence*) contrasts to identify the common regions in the two processes (Supplementary Fig. 4). Three regions – dorsomedial prefrontal cortex (dmPFC), precuneus, and angular gyrus – were preferentially engaged by Tailored messages and by self-related processing. We then examined whether the neural response to Tailored messages in these functionally defined regions predicted smoking-cessation outcome at the 4-month follow-up. The average beta parameter estimate for all voxels in the three identified regions for the *Tailored* > *Neutral* contrast was used as a predictor in a logistic regression. Greater neural response to Tailored messages in the entire common region significantly predicted the odds of quitting smoking at 4 months, (ß = .31, *S.E.* = 14, Wald χ^2 = 5.21, p = .022; O.R. = 1.36). We then examined the three regions individually to see if activation in each region predicted quitting. The average beta across the voxels in each of the three regions was used as a predictor in logistic regression models. We found that greater activation in dmPFC during Tailored messages (BA 9,10; peak xyz coordinates: 0, 54, 30; k = 128; ß = .27, *S.E.* = .11, Wald χ^2 = 5.71, p = .017; O.R. = 1.31) significantly predicted the odds of quitting smoking. Similarly, greater activation in the precuneus (BA 31, 7; peak xyz coordinates = −6, −51, 36; k = 30; ß = .22, *S.E.* = .12, Wald χ^2 = 3.11, p = .078; O.R. = 1.24) marginally correlated with smoking abstinence at 4-months (Fig.1). The activation in angular gyrus did not predict quitting (BA 39; peak xyz coordinates: −51, −63, 33; k = 30; ß = .06, *S.E.* = .12, Wald χ^2 = 0.34, *ns*; O.R. = 1.07). In the above logistic regression models, we controlled for the effects of number of cigarettes per day, which was independently negatively correlated with quitting, r = −.23, p = .033.

To our knowledge, this is the first study to demonstrate a direct link between the neural response to tailored messages and real-life smoking cessation. Greater activation in regions preferentially engaged by tailored messages and self-related processing was associated with smoking abstinence at 4 months, following a tailored-message smoking-cessation intervention.

Our findings suggest that the advantage of tailored health messages in promoting a desirable health-behavior change stems at least in part from enhanced engagement of self-related processes evoked by tailoring. Specifically, the dmPFC region has been associated with the evaluative and decision making aspects of self-related processing[12], which could underlie the efficacy of tailored message interventions. The engagement of self-related processing could allow for deeper processing and more efficient integration of the newly formulated health-change goals into one's learning, self-schema and action plans, culminating in behavioral change. Indeed, follow-up reports indicate that Quitters were more likely to change their behavioral response to stress and to avoid situations that trigger smoking following the tailored smoking-cessation program (see Supplement).

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This study provides a first and important step in identifying neural mechanisms associated with eliciting a real-life health-behavior change through tailored health communications. It is our belief that the addition of neuroimaging methods to the already powerful convergence of health communication techniques and information technology will promote rapid progress in facilitating psychoneurobiological understanding of behavior change leading to improved tailored health intervention programs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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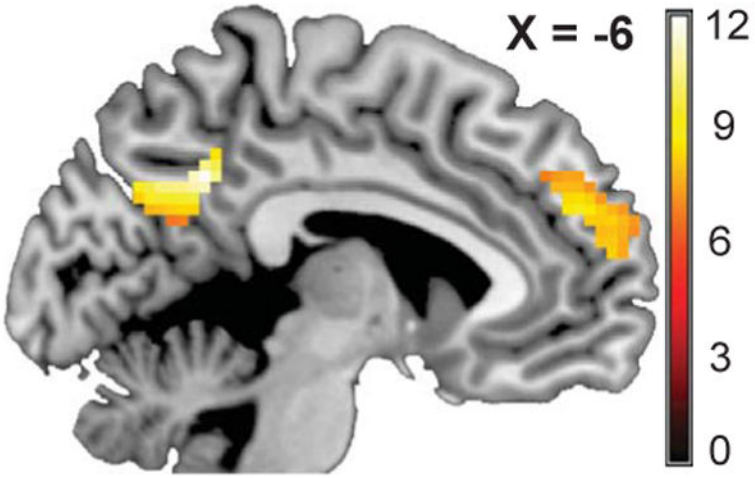

Fig. 1.

Brain region activations during Tailored messages associated with quitting. Greater dmPFC activation predicted quitting and greater precuneus activation marginally predicting quitting. Regions are defined by areas preferentially engaged during Tailored messages in contrast to Untailored messages and also self-related processing in the Self-Appraisal task. The color map depicts the *t*-score and image coordinates are in MNI space.